Game Theory:
A Strategic Tool in Decision-making & Policy

The political process intrinsically involves many different stakeholders with conflicting interests. For a governing body to successfully impose a new law, there are questions for which it would be helpful to know the answers. "Who are our most powerful opponents? Proponents?" "What is the most fair way to impose this law?" "Which proposal is most likely to succeed?" "Which one is most likely to fail?" "Who gains and who loses?" Game theory attempts to answer all of these questions. Some methods are concerned with fairness, like the Shapley value. Other techniques are more concerned with bargaining and negotiating, such as the nucleolus and Gately point. The goal of this paper will be to provide a general introduction to game theory, as well as describe some of the specific techniques mentioned above.

Overview

The theory of games is a theory of decision-making.[i] Game theory was created as a tool to mathematically model complex situations, or games. Typically games model situations where one or more parties (players) have conflicting interests. Examples of players are wide-ranging: everything from political parties, governments, and businesses to prison inmates and professional sports franchises. The goal of a game theorist is to predict the decisions and outcomes of the "players" of a "game". Game theory is not used to predict "winners" and "losers". The aim is not to tell you how to play the game, but to tell you certain properties involved with different ways of playing the game that might prove valuable[ii].

Game theory is rooted in mathematics. As such, it can at times be complex and tedious in both its descriptions and applications. The real value of game theory, however, is not in the application of numbers to formulas, but in the critical thinking and deduction used in the analysis of a given game. The context of this paper will be non-technical. The goal here will be to introduce game theory without getting bogged down in all of the math involved. First, an introduction will be given to some basic game theoretical constructs. Next, we can explore some specific theories and applications of game theory that might prove useful to CALFED.

History

In 1944, *The Theory of Games and Economic Behavior* by John von Neumann (a mathematician) and Oskar Morgenstern (an economist) was published. Although some of the basic ideas behind 2-person game theory were discussed and published earlier, this book is widely regarded as *the* seminal work in game theory. This book was also the first to introduce n-person games and develop solutions for them. Game theory has since grown from its inception in math and economics and has spread to the fields of political science, psychology, sociology, and biology. In 1994, the Nobel Prize in economics went to the game theorists John C. Harsanyi, John F. Nash, and Reinhard Selten.

Key Concepts/Definitions

Game theory can be useful in a variety of games, from the very simple to the most complex. There are two basic types of games: 2-person games and n-person games. 2-person games are more simplistic, because they apply to situations with only two players. N-person games are more complex, but they better model realistic situations with multiple players. It will be helpful to briefly introduce 2-person game theory, but 2-person games won't be stressed in this paper.

Probably the most well known example of a strategic 2-person game is the prisoner's dilemma. Because it is simple to understand and so famous, it would be remiss not to mention it here. Two suspects in a major crime are caught and brought in for questioning. They are placed in separate interrogation rooms. There is enough evidence to convict both of them on a minor offense, but without a confession from one or both of them there is not enough evidence to convict either of them of the major crime. If both of the suspects keep quiet, they will be convicted of the minor offense and each will spend one year in jail. If one of the suspects keeps quiet, but the other one "finks" on his partner, then the suspect who kept quiet will get five years in prison, while the informant (the one who "finked") will go free with no jail time. If both suspects fink on each other, then they each get four years in prison. What will they do?

Obviously, there are benefits to both suspects from cooperation and keeping quiet. Each suspect would prefer that they both keep quiet (one year of jail) to both finking (four years of jail). What happens is just the opposite. Both suspects will fink. The dilemma is that the two subjects are in separate rooms, and therefore neither suspect knows what decision the other will make. Each suspect must analyze the situation and make a decision that will benefit himself the most, (or in this case, hurt himself the least) based on what he thinks the other suspect will do. For example, let's say you are a suspect. No matter what you predict the other suspect will do, it is always in your best interest to fink. If the other suspect is quiet, then it benefits you to fink, because then you go free instead of spending a year in jail. If the other suspect finks, then you should also fink, because four years in jail is better than five.

An example of the prisoner's dilemma for n-person game theory is the "tragedy of the commons." Say you are a farmer that shares ground water with multiple other farmers. It would be in all of the farmers' best interests to agree to conserve the water and only use it at a sustainable rate. The problem arises when either there is no agreement or one of the farmers breaks the agreement. As soon as other farmers aren't conserving the water, then it doesn't make sense for you to conserve it either. The water will be all gone soon whether you conserve or not, so you might as well get as much as possible while you still can.

The previous examples should give an idea of the kinds of situations game theory addresses. Before we can move on any further with our discussion, however, we need to define some of the language used in game theory.

A **game** is a theoretical model of a conflict of interest.[iii] **Players** are participants in the game. A **coalition** describes a joining together of different players in a game to act as one. A **pay-off** is what a given player or coalition gets at the conclusion of a game. **Utility** at the end of a game can be used to show a player's preferences. A **strategy** describes all of the possible decisions a player will make at different points in the game, depending on the situation.

N-person games are analyzed using **characteristic function form**. "The characteristic function of an n-person game assigns each subset S of the players the maximum value v(S) that coalition S can guarantee itself by coordinating the strategies of its members, no matter what the other players do."[iv] In other words, each coalition (S) is assigned a number V(S), which describes the value, or minimum pay-off, that a coalition can expect to get by joining together as a team.

An **imputation** is a reasonable way of dividing the pay-offs among the individual players who join a coalition. There is not just one imputation that "solves" the game. There are multiple possible imputations that are **individually rational**[v]. That is, each player will obtain a pay-off at least as high from joining the coalition as she would from remaining alone. An imputation is **coalitionally rational** if all of the members of the coalition receive a pay-off at least as great as their individual value[vi]. These coalitionally rational imputations make up what is called the **core**. Games without a core are unstable, because there is always an individual or a coalition that has more to gain by going it alone than by joining the **grand coalition**, where all of the players in the game join together.

How can Game Theory be helpful in the political planning process?

There are multiple uses for game theory in the political process. One is for strategic planning. Game theory is a useful tool in the bargaining and negotiating process. It can also be helpful in trying to determine a fair solution to a problem. Game theory can also be used as a cost allocation tool, once a solution has been decided upon. Shapley values, the nucleolus, and the Gately point are all game theoretic techniques that can be used in cost allocation or as strategic political tools.

Shapley Values

In 1953, Lloyd Shapley looked at n-person game theory in a different way. His goal was to determine the value of a given game for a particular player. Given the characteristic function of a game, Shapley outlined a method for determining the worth of a game to each player. Hence, these "values" are called Shapley values. If you make the assumption that a coalition will form among all the players, the marginal gain that each player will get by joining the coalition versus not joining would be that player's Shapley value.

In 1954, The *Shapely-Shubik power index* was introduced as an application of the Shapley value to voting games. It determines which coalitions are the most powerful. While the abstract numbers that it generates are not perfectly representative of the real world, the Shapely-Shubik power index is widely accepted, and it does do a good job of showing power relationships for the players in a game.

Nucleolus

In some games, there is an empty core. In other words, there are some coalitions that might be considered necessary, or better for society as a whole, but not everyone who is in the coalition will benefit by joining. The nucleolus can be helpful in these cases, because it will try to find a solution that is as close to the core as possible, even if it isn't contained within it. The goal of the nucleolus is to find the imputation that will make the most unhappy player or coalition as little unhappy as possible[vii]. In other words, try to *minimize* the largest difference between what the player or coalition would gain independent of the grand coalition over what can be gained from the grand coalition. According to Josh Billings, "the wheel that squeaks the loudest is the one that gets the grease."[viii] Using this analogy, the nucleolus tries to make the squeakiest wheel squeak as little as possible.

The Gately Point

The Gately point is similar to the nucleolus, but instead of minimizing maximum unhappiness, the goal of the Gately point is to find the imputation that will minimize the maximum propensity to disrupt the coalition. The Gately point is the point where every player has the same propensity to disrupt. At first glance, this appears to be the same as the nucleolus, because it would seem that the player that is the most unhappy would be the one most likely to disrupt the coalition. This isn't always the case however. For example, consider a game where you have three players: x, y, and z. Let's assume all three players gain from forming a coalition, but players y and z have the most to gain. Player x has something to lose if he disrupts this grand coalition, but players y and z have much more to lose. Player x might threaten disruption of the coalition and demand more utility be transferred to him, because he knows that y and z desperately need him to join the coalition.

What are the limitations of using Game Theory as a political tool?

Game theory can be very useful, but it does have its limitations, especially with n-person games. While game theoretical models attempt to predict what will happen in the real world, it is impossible to do this with perfect accuracy, because there is no way to include *all* of the variables in a model. In addition, a model is only as good as its characteristic function. When assigning values to coalitions in a characteristic function, you have to make an educated guess in assigning these values or have very accurate data about all of the players in the game.

Game theoretical models of real problems do not give you one "solution," but they can predict what types of decisions by different players are probable, and which ones can be ruled out. Game theory can also tell you which players are likely to work together and which ones will work against each other.

How does this all relate to CALFED?

In terms of CALFED, game theory could be very helpful in the analysis and determination of a preferred alternative. It could be useful to know which stakeholders would gain the most (Shapley values) from a given alternative, and which ones would be the most unhappy with the chosen alternative (nucleolus). The Gately point serves as a tool to predict which stakeholders would be most likely to try to sabotage a given alternative, and the Shapley-Shubik power index could tell you which ones have the power to do so. When developing a strategy to successfully enact whichever alternative is finally chosen, these techniques, and the thought processes that they create, would be very helpful.

Another possible use of game theory for CALFED would be in the allocation of costs of the program. For example, the costs of the program (coalition) could be allocated based on the Shapley values for each stakeholder (player). In this case, the Shapley value for a given player would be the average marginal gain, brought to the coalition by this player, of all the possible orderings of the coalition. By taking into account all of the possible orderings for the coalition, the Shapley value accounts for multi-user benefits. The Shapley value tries to find the imputation, or solution, that is the most "fair". The nucleolus and the Gately point are more concerned with bargaining and negotiation than fairness, but they can also be used for cost allocation.

Game theory is a valuable technique that enjoys widespread use in many different fields. While it is not a perfect tool, and it doesn't provide you with *the* correct answer, game theoretical applications can lead to thinking about problems and solutions in a different way than you might have done without it. Whether you are trying to pick an alternative, build a successful assurances package that will be acceptable to the stakeholders, or allocate the costs to pay for the program, game theory can be a valuable tool.

[i] Davis, Morton. *Game Theory: A Nontechnical Introduction*, p 3. New York: Basic Books, 1983.
[ii] Thomas, L.C. *Games, Theory, and Applications*, p 17. New York: Halsted Press, 1984.
[iii] Thomas, L.C. *Games, Theory, and Applications*, p 15. New York: Halsted Press, 1984.
[iv] Thomas, L.C. *Games, Theory, and Applications*, p 86. New York: Halsted Press, 1984.
[v] Davis, Morton. *Game Theory: A Nontechnical Introduction*, p 184. New York: Basic Books, 1983.
[vi] Davis, Morton. *Game Theory: A Nontechnical Introduction*, p 184. New York: Basic Books, 1983.
[vii] Straffin, Philip D. *Game Theory and Strategy*, p 202. New York: The Mathematical Association of America, 1993.
[viii] Straffin, Philip D. *Game Theory and Strategy*, p 202. New York: The Mathematical Association of America, 1993.

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